

**N^* Resonances in Pseudoscalar-meson photo-production
from Polarized Neutrons in $\vec{H} \cdot \vec{D}$
and a complete determination of the $\gamma n \rightarrow K^0 \Lambda$ amplitude**

Collaboration

K. Ardashev¹⁸, N. Benmouna⁷, M. Blecher¹⁹, D. Branford⁵, W. Briscoe⁷, V. Burkert¹²,
P. Cole²⁰, V. Crede²¹, A. D'Angelo¹³, D.S. Dale²⁰, R. Di Salvo¹⁴, A. Fantini¹⁴, R. Gothe¹⁷,
K. Hicks¹¹, S. Hoblit², D. Ireland¹⁶, B. Juliá-Díaz¹⁵, T. Kageya¹⁹, J. Kellie¹⁶, M. Khandaker¹⁰,
O.C. Kistner², F. Klein⁴, T.S.-H. Lee¹, P. Levi Sandri⁹, R. Lindgren¹⁸, K. Livingston¹⁶,
M. Lowry², J. Mahon¹¹, L. Miceli², D. Moricciani¹⁴, B. Norum¹⁸, J. Price³, G. Rosner¹⁶,
A.M. Sandorfi², C. Schaerf¹³, D. Sober⁴, I. Strakovsky⁷, S. Strauch¹⁷, H. Ströher⁶,
D. Tedeschi¹⁷, C. Thorn², X. Wei², K. Wang¹⁸, D. Watts⁵, C.S. Whisnant⁸ and R. Workman⁷

and

the CLAS Collaboration

- ¹Argonne National Laboratory, Argonne, IL 60439
- ²Brookhaven National Laboratory, Upton, NY 11973
- ³California State University at Dominguez Hills, Caeson, CA 90747
- ⁴Catholic University of America, Washington, DC 20064
- ⁵Edinburgh University, Edinburgh EH9-3JZ, UK
- ⁶Forschungszentrum Jülich, D-52425 Jülich, Germany
- ⁷George Washington University, Washington, DC 20052
- ⁸James Madison University, Harrisonburg, VA 22807
- ⁹Laboratori Nazionali di Frascati-INFN, 00044 Frascati, Italy
- ¹⁰Norfolk State University, Norfolk, VA 23504
- ¹¹Ohio University, Athens, OH 45701
- ¹²Thomas Jefferson National Accelerator Facility, Newport News, VA 23606
- ¹³Universita di Roma-“Tor Vergata” and INFN-Sezione di Roma Tor Vergata, 00133 Rome, Italy
- ¹⁴INFN-Sezione di Roma Tor Vergata, 00133 Rome, Italy
- ¹⁵Universitat de Barcelona, 08028 Barcelona, Spain
- ¹⁶University of Glasgow, Glasgow G12-8QQ, UK
- ¹⁷University of South Carolina, Columbia, SC 29208
- ¹⁸University of Virginia, Charlottesville, VA 22904
- ¹⁹Virginia Polytechnic Institute & State University, Blacksburg, VA 24061
- ²⁰Idaho State University, Pocatello, ID 83209
- ²¹Florida State University, Tallahassee, FL 32306

Abstract

The internal structure of the nucleon, as manifested in its excitation spectrum, has presented a crucial challenge to nuclear and elementary-particle physics. The quark model predicts many resonances that appear to be *missing* from the spectrum of πN states. However, the quark model also predicts a rapid decrease with energy in the $G_{\pi N}$ coupling for the states in each oscillator band. Higher mass states may couple to other pseudoscalar meson channels such as $\pi\pi N$, ΔN , ρN , ωN , ηN , $K\Lambda$ or $K\Sigma$. Alternatively, other models involving diquarks or phase transitions have been proposed to account for the current baryon spectrum, which is chiefly determined from πN reactions. The apparent success of such alternatives questions the effective degrees of freedom within the nucleon.

Higher mass resonances are generally overlapping with significant interfering backgrounds from u -channel processes. As a result, their properties cannot be extracted without detailed partial-wave analyses, preferably in a frame-work which accounts for the coupling between the various meson-decay channels. Constraining such analyses requires a large number of polarization observables. This has not been achieved in any channel, despite nearly 50 years of research into πN scattering and photo-production. Most of the available data has been taken with proton targets and a new set of polarized target experiments will soon expand this data base at JLab. In contrast, the available neutron data is extremely sparse. While $I = 3/2$ Δ resonances can be determined from proton data alone, $I = 1/2$ N^* resonances necessarily require *both* neutron and proton data.

We propose to measure a suite of pseudoscalar-meson photo-production reactions using circularly and linearly polarized beams on a longitudinally polarized deuterium target. We have considered two possible frozen-spin targets, a deuterated-butanol version of the FROST target now under construction at JLab and the HD target which has been developed at BNL, and have carried out detailed simulations for each. Since anticipated running times with Butanol are factors of at least 15-25 times longer, depending on kinematics, we plan to use a polarized HD target.

Asymmetries from *free* neutrons will be isolated by kinematically restricting the meson-baryon decay. Beam-target double-polarization asymmetries for the πp , $\pi^+\pi^-n$, $K^0\Lambda$, $K^0\Sigma^0$ and

$K^+\Sigma^-$ channels will all be measured simultaneously. Since the weak decay of the hyperons provides an analysis of their recoil polarization, target-recoil and beam-recoil data will also be measured for those channels. The simultaneous measurement of beam-recoil asymmetries from the neutron, using the same kinematic restrictions, is possible because the target molecule contains a single neutron in deuterium and the small contaminations from non-HD material in the beam path can be subtracted from concurrent empty cell measurements.

The recoil analyzing power in Λ decay is appreciable and this provides a unique opportunity. For the $\gamma n \rightarrow K^0 \Lambda$ reaction, a total of 13 different polarization observables will be determined in a single experiment, including single-polarization and beam-target, target-recoil and beam-recoil double-polarization asymmetries, along with the cross section. This will provide the first (over-) determination of a pseudoscalar meson photo-production amplitude and will be free of the PWA ambiguities that have plagued this field for decades.

A small fraction of running is also planned for polarized H which will verify the effectiveness of kinematic requirements in the extraction of neutron observables, by comparing *free* protons in H and *bound* protons in D, and set limits on possible corrections to the neutron asymmetries from deuteron tensor observables. At the same time, this will provide polarized proton data on beam-target and target-recoil asymmetries taken under the same conditions and so create a uniquely large data set on both isospin channels that is locked together with common systematics. When combined with other proton beam-recoil measurements, this will determine the complete $\gamma N \rightarrow K \Lambda$ isospin amplitude, free of ambiguities.

The total beam request for this experiment is 75 days with polarized $H\vec{D}$ and 10 with polarized $\vec{H}D$, for a total of 85 days.